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SOCKEYE SALMON (ONCORHYNCHUS NERKA) ESCAPEMENTS TO SOUTHERN SOUTHEAST ALASKA IN 1982 AND 1983

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ABSTRACT

Sockeye salmon (Oncorhvnchus nerka) escapement to 59 lake systems in southern Southeast Alaska was estimated as part of joint U.S./Canada research on interceptions in boundary region fisheries of Alaska and British Columbia. Escapements to individual lakes were counted or estimated in 1982 and 1983. Counts were made from weirs and estimates were made by Petersen experiments or corrected counts of stream surveys. Information from these sources was extrapolated to unexamined lakes and total escapement was educed. Estimates of total escapements were 354,000 in 1982 (90% confidence interval (CI), 254,000-477,000) and 324,000 in 1983 (90% CI, 216,000-458,000). These results represent the first reliable estimates of Alaskan sockeye salmon escapement for this region.

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INTRODUCTION

Between 1924 and 1968 sporadic tagging studies on sockeye salmon (Oncorhvnchus nerka) in boundary region fisheries of Southeast Alaska and northern British Columbia (Williamson 1925; Rich 1932; Noerenberg and Tyler 1971) demonstrated U.S. and Canadian fishermen caught mixtures of fish from both countries. These sockeye salmon were primarily of stocks originating from northern British Columbia or southern Southeast Alaska (Fig. 1). Beginning in 1982 and continuing in 1983, the United States and Canada - cooperated in a tagging program to estimate interceptions of sockeye salmon returning to the fisheries on both sides of the border..

Developed to estimate national composition of catches in the affected fishing areas, this research program included releases of tagged adult fish from each fishery during the season, with subsequent monitoring of catches and escapements for the tagged fish. Accurate counts or estimates of the number of tagged fish returning to either country were essential to the program.

The main Canadian sockeye salmon stocks contributing to the border fisheries were believed to originate from the Skeena, Nass, and Stikine Rivers. Historical information on run sizes and timing was available, and weir structures within these rivers facilitated the recovery and counting of tagged fish.

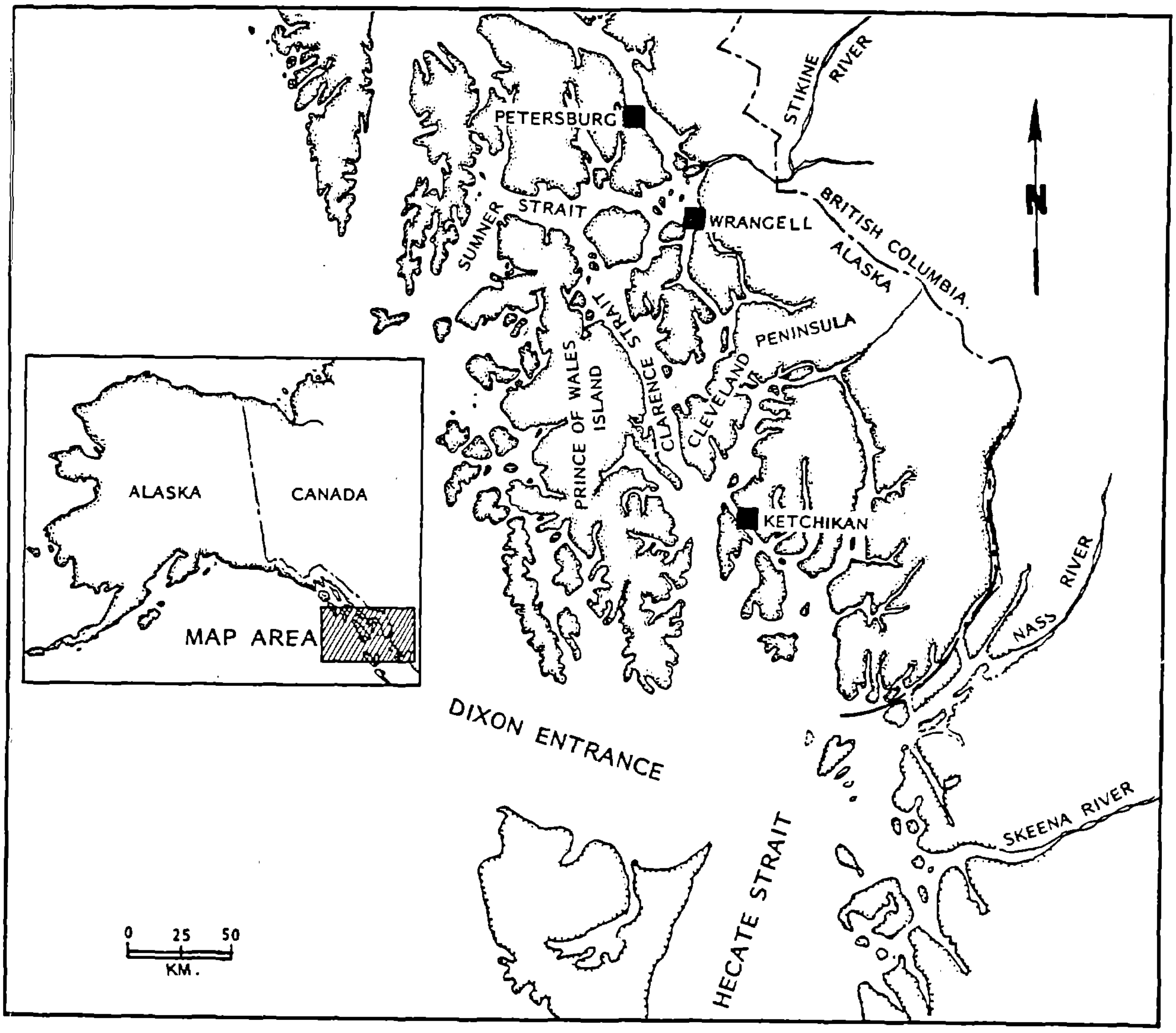

Figure. 1--Boundary area of southern Southeast Alaska and northern British Columbia.

Compared to Canadian fish, fewer sockeye salmon of southern Southeast Alaska origin were affected by intercepting fisheries in the border region. These sockeye salmon were from the numerous small watersheds that are scattered throughout a vast (about 50,000 km^2), sparsely populated, and mostly roadless region. Initial information on the magnitude and seasonal timing of migration and spawning of adults of most Southeast Alaska populations was conjectural.

Recovery and counting of tagged sockeye salmon from all populations of southern Southeast Alaska was not feasible. Instead, the escapement of tagged fish was estimated from the total escapement of sockeye salmon and the proportion of fish that were tagged. This report covers only that part of the U.S. program concerned with the estimation of the sockeye salmon escapement to southern Southeast Alaska during the summers of 1982 and 1983. The estimates constituted a critical ingredient in the calculations of interceptions, and may be useful in management of fisheries of Southeast Alaska by providing a benchmark against which future escapements can be compared.

METHODS

United States scientists from the Alaska Department of Fish and Game (ADF&G) and the Northwest and Alaska Fisheries Center Auke Bay Laboratory conducted a two-stage program to estimate the size of the sockeye salmon escapement to southern Southeast Alaska. First, weirs were installed on outlet streams of selected lake systems to allow the counting of escapements. In this part of the program, fairly accurate escapement counts could be obtained under ordinary circumstances. However, weirs are costly and only a fraction of the systems could be covered. Therefore, in the second stage of the program, the number of fish in combined escapements to rivers without weirs was estimated. Petersen tagging experiments (secondary studies at the lake systems as opposed to the tagging done in the ocean) and stream surveys on a sample of the lake systems without weirs, provided data for the, extrapolation of total escapement.

After discussions with natural resource personnel of the region and an examination of stream survey counts, 59 lake systems were identified as significant producers of sockeye salmon (Fig. 2). Of the 59 systems, 12 were identified by fishery managers as often having very large escapements (these systems are denoted as class V). The class V systems are distributed over the region; eight occur on Prince of Wales Island, two on the mainland, and two on smaller islands (Figs. 1, 2; Table 1). The remaining 47 systems were classified by probable magnitude of escapement into large (L) I medium (M), and small systems (S) (Table 1).

Counts of escaping sockeye salmon were made at weirs for 9 of the 12 class V systems, 1 class L lake, and 1 class M lake in 1982 and 1983 (Table 2). In some cases, counts through weirs were known to be incomplete (Table 2).

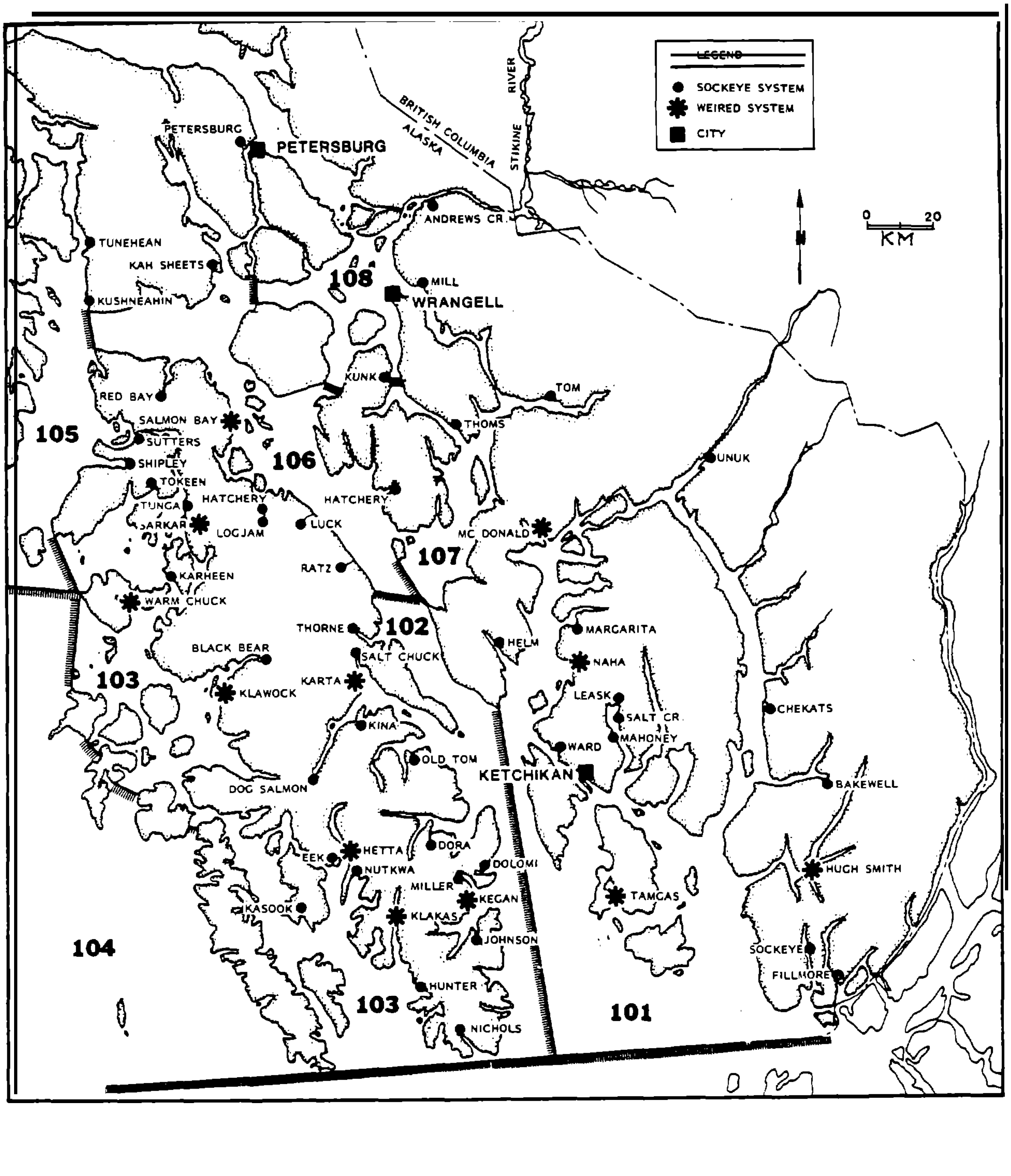

Figure 2.--Sockeye salmon systems and Alaska Department of Fish and Game fishing districts 101-108 in southern Southeast Alaska.

Table 1.--Place names and stream number[a] of significant sockeye salmon systems in southern Southeast Alaska, classified by probable magnitude of escapement into very large (V), large (L), medium (M), and small (S) systems .

<u>Class V</u> (n = 12)
Hugh Smith (101-30-075), McDonald (101-80-068), Naha (101-90-050), Kegan (102-30-067), Karta (102-60-087), Sarkar (103-90-014), Klakas (103-15-027), Hetta (103-25-047), Klawock (103-60-047), Luck (106-10-030), Salmon Bay (106-41-010), Thoms (107-30-030)

<u>Class L</u> (n = 11)

Fillmore (101-11-079), Tamgas (101-25-025), Helm (101-90-084), Dolomi (102-20-040), Thorne (102-70-058), Kushneahin (105-31-003), Shipley (105-43-002), Logjam (106-30-053), Red Bay (106-41-030), Kah Sheets (106-42-010), Petersburg (106-44-060)

<u>Class M</u> (n = 10)

Nichols (102-10-060), Johnson (102-30-017), Kina (102-60-068), Hunter (103-11-017), Nutkwa (103-21-008), Eek (103-25-009), Black Bear (103-60-031), Warm Chuck (103-80-031), Ratz (106-10-010), Hatchery (106-30-051)

<u>Class S</u> (n = 26)

Chekats (101-51-06), Sockeye (101-11-039), Lucky Cove (101-41-025), Mahoney (101-45-016), Leask (101-45-032), Salt (101-45-038), Ward (101-47-015), Bakewell (101-55-073), Unuk (101-75-030), Margarita (101-90-039), Dora (102-40-033), Miller (102-30-089), Old Tom (102-60-024), Dog Salmon (102-60-038), Salt Chuck (102-60-095), Karheen (103-90-0693), Tunga Inlet (103-90-009), Kasook (103-40-058), Tokeen (103-90-072), Tunehean (105-32-004), Sutters (105-42-014), Hatchery (106-21-003), Kunk (107-30-095), Mill (107-40-007), Tom (107-40-047), Andrew (108-40-020)

[a]Alaska Department of Fish and Game uses this code to uniquely identify streams. The three parts refer to fishing district, subdistrict, and stream number, respectively.
[b]Very large systems were identified by fishery managers as often constituting a significant part of regional escapement within Southeast Alaska. We classified remaining systems: large systems have had peak counts or season totals in excess of 5,000; medium systems, between 1,000 and 5,000; and small systems, less than 1,000.

Table 2.--Dates of operation and escapement counts of sockeye salmon in southern Southeast Alaska systems with weirs, 1982 and 1983.

System	Class	1982 Dates	1982 Count	1983 Dates	1983 Count	Count ratio (1983/1982) x 100
Hugh Smith	V	June 6-Nov. 26	57,224	June 1-Sep. 3	10,058	17.6
McDonald	V	July 2-Sep. 12	16,650	July 9-Sep. 1	56,147	337.2
Naha	V	Not operated	-	June 13-Aug. 26	4,679[a]	-
Kegan	V	June 19-Sep. 20	14,485	June 15-Sep. 12	8,751	60.4
Karta	V	June 24-Sep. 22	41,481	June 18-Sep. 11	22,532	54.3
Sarkar	V	June 14-Aug. 22	8,157	June 19-Aug. 19	2,680	32.9
Hetta	V	June 16-Aug. 27	5,387	Not operated	-	-
Klakas	V	July 29-Oct. ?	2,076[a]	June 8-Nov. 11	1,413	-
Klawock	V	June 18-Oct. 10	4,812	July 7-Oct. 10	839	17.4
Salmon Bay	V	June 26-Sep. 2	16,042	June 12-Aug. 26	14,023	87.4
Warm Chuck	M	Aug. 24-Oct. ?	1,781[a]	June 19-Oct. 18	3,395	-
Tamgas	L	? -Sep. 9	1,696	June 17-Sep. 30	922	-[b]

[a]An unknown part of the run passed the weir uncounted.
[b]An eradication program at Tamgas invalidates a comparison between years, and counts at the weir represent only an unknown part of the return to this system.

Populations of sockeye salmon in each of the classes were included for secondary tagging or stream survey when the opportunity was available. Secondary tagging began in early July and ended in mid-August each year (Tables 3, 4). The outlets of the lakes at salt water were examined by a tagging crew for presence of returning spawners. When sockeye salmon were detected, the crew tagged as many of the fish as could be caught within a day or two.

The cost and time requirement of searching for spawners at outlets limited the number of systems that could be examined and the number of reexaminations of any system. The occurrence of returning spawners near an outlet stream with the tagging crew nearby was somewhat fortuitous, although chances were probably improved by synchronizing the location of the crew and their vessel with the surmised timing of return of sockeye salmon populations within Southeast Alaska.

Sockeye salmon were captured in salt water near (<0.5 km) the stream mouths when the search was successful. Some fish were, captured by beach seining, but most were taken by hand purse seining. Petersen disc tags (3.18-cm diameter) were used; their colors, either solid yellow or tricolored orange-yellow-red, distinguished them from the bright-red primary tags used in the ocean fisheries. Tagged fish released in different systems were distinguished by large letters printed on the

Table 3.--Secondary tag and recovery information for sockeye salmon systems in southern Southeast Alaska, 1982.

Class	System	Tagging dates	Number tagged	Survey dates	Sockeye seen[a] Live	Sockeye seen[a] Dead
V	Naha	July 13-14	67	Sep. 16-Sep. 20	6,029 (5)	479 (0)
	Klakas	July 18-19	539	Sep. 15	3,395 (6)	432 (2)
				Sep. 24	2,000 (3)	3,000 (5)
	Thoms	July 9-10	106	Sep. 3	3,221 (5)	217 (0)
				Sep. 21	15 (0)	2,074 (3)
	Luck	-	0	Sep. 22	313 (0)	474 (0)
L	Helm	July 11-13	225	Sep. 15	880 (7)	210 (1)
				Sep. 20	247 (3)	434 (5)
	Fillmore	-	0	Sep. 1	600 (0)[c]	
				Sep. 23	122 (0)	17 (0)
	Kushneahin	Aug 9-11	489	Aug. 17	445 (2)[c]	
				Aug. 24[b]	2,000 (45)	0 (0)
				Sep. 18	289 (0)	39 (0)
				Sep. 25	329 (0)	52 (0)
				Oct. 7	155 (0)	[d] (0)
	Shipley	Aug 13	502	Sep. 17	352 (7)	10 (0)
				Sep. 25	333 (7)	18 (0)
	Red Bay	-	0	Sep. 20	1,299 (0)	1,609 (0)
M	Warm Chuck	-	250	Sep. 19	1,059 (3)	385 (0)
				Oct. 11	2,253 (63)	1,322 (3)
	Hunter	July 20	34	-	-	-
	Eek	-	0	Sep. 18	846 (0)	46 (0)
	Ratz	-	0	Sep. 22	214 (0)	70 (0)

Table 3. --Continued.

Class	System	Tagging dates	Number tagged	Survey dates	Sockeye seen[a] Live	Sockeye seen[a] Dead
S	Sutters	Aug 14	47	Sep. 16	202 (0)	540 (7)
	Leask		0	?	644 (0)[c]	
				Sep. 19	150 (0)	215 (0)
	Sockeye		0	Sep. 23	750 (0)	87 (0)

[a]Number with tags is in parentheses.
[b]Rough counts were made in the estuary but were not used in estimating escapement.
[c]Only live and dead total was recorded.
[d]Not recorded.

Table 4.--Secondary tag and recovery information for sockeye salmon systems without weirs in southern Southeast Alaska, 1983.

Class	System	Tagging dates	Number tagged	Survey dates	Sockeye seen* Live	Sockeye seen* Dead
V	Luck	-	0	Sep. 2-Sep. 3	5,333 (0)	42 (0)
	Thoms	-	0	Sep. 7	1,545 (0)	1,460 (0)
L	Helm	July 8-9	334	Sep. 7	323 (25)	212 (12)
				Sep. 16	53 (2)	289 (25)
				Oct. 5	0 (0)	303 (18)
	Dolomi	July 10-11, 17	353	Sep. 7	172 (3)	3 (0)
				Sep. 15	178 (3)	15 (0)
				Oct. 5	960 (26)	96 (0)
	Shipley	Aug. 3-4	490	Sep. 9	79 (4)	0 (0)
		Aug. 9-10	179	Sep. 17	397 (32)	9 (0)
		Aug. 16	47	Oct. 5	585 (82)	45 (2)
	Red Bay	-	0	Sep. 3	2,623 (0)	357 (0)
	Kushneahin	-	0	Sep. 9	167 (0)	3 (0)
	Hatchery (Prince of Wales Island)	-	0	Sep. 18	30 (0)	508 (0)
M	Johnson	-	0	Sep. 7	1,259 (0)	24 (0)
	Ratz	July 20	8	Sep. 18	45 (0)	6 (0)
S	Miller	July 1-18	108	Sep. 7	22 (1)	0 (0)
				Sep. 15	211 (5)	0 (0)
				Oct. 5	2,142 (31)	20 (0)
	Karheen	Aug. 5-6, 8	100	Sep. 6	638 (31)	0 (0)
				Oct. 5	5 (0)	110 (5)

*Number with tags is in parentheses.

discs; these features made time-consuming physical recovery unnecessary in counting the marked fish in the surveys.

Surveys to count fish of secondary tagged populations were conducted during September and October in 1982 and 1983. Recovery teams for surveys were usually flown to and from the lakes each survey day. These teams counted live and dead untagged and secondary tagged fish (Tables 3, 4). Counts were usually made in all tributaries to the lakes until barriers to fish migration were encountered. In some cases, lake spawners were visible and they were also counted. The systems were surveyed once or twice, depending on the stage of spawning at the first visit: if spawning was in early stages at the first visit, a second survey was conducted. Relative numbers of live and dead fish indicated the stage of spawning activity, ranging from the early spawning stage with most fish alive to the late stage with most fish dead. Cost of air transportation prevented additional surveys. Surveys of systems in which no secondary tagging occurred were performed when the opportunity was available; weather, logistics, and funds for aircraft support were limiting.

The basic program was modified in 1983 with the addition of experiments to examine the validity of assumptions of the Petersen experiments, and to compare visibilities of primary tags and the two secondary tags. To evaluate the validity of our application of the Petersen method, taggings were conducted in salt water at the outlets of three systems with weirs, thus allowing the comparison of estimates with weir counts. The systems chosen were Kegan, Salmon Bay, and Warm Chuck (Table 5). The methods of tagging used to estimate escapements to systems with weirs were the same as in the secondary tagging experiments, but more surveys were conducted during these validation studies.

Studies to compare tag visibilities were done by tagging from the weirs at two class V systems--Klakas and Naha (Tables 5, 6). The three colors of tags (bright-red primary, solid-yellow secondary, and tricolored secondary) were placed in sequence on sockeye salmon as they passed the weirs. Sockeye salmon carrying bright-red primary tags from ocean taggings were captured and retained at the weirs. Both systems were surveyed repeatedly to provide observations for comparison of tag colors. These studies provided information on tag visibility, and also allowed further comparison of weir counts with Petersen estimates.

Computation of escapement to any lake system based on tagging used simple modifications of Chapman's version of the Petersen estimator (Ricker 1975) to account for mortality of tagged fish and repeated surveys on tagged populations. Variables used were the number of sockeye salmon seen (alive or dead), the number of tags observed, and the number of tagged fish which entered the lake. If the lake system was weired, the number of entering tagged fish was known; otherwise it was computed from the tagging survival rate estimated from systems with weirs multiplied by the number of tagged fish released. The modified estimator was a weighted average of population estimates from the individual surveys; the weights were the

Table 5.--Secondary tag and recovery information for sockeye salmon systems with weirs in southern Southeast Alaska, 1983.

Class	System	Tagging dates	Number tagged	Survey dates	Sockeye seen[a]	
					Live	Dead
V	Kegan	July 13-14	494	Sep. 7	727 (32)	5 (0)
				Sep. 14	1,008 (48)	14 (1)
				Oct. 5	1,505 (18)	129 (0)
	Salmon Bay	July 21-22, Aug. 2	506	Sep. 8	3,755 (27)	744 (7)
				Sep. 18	1,521 (2)	1,538 (8)
	Klakas[d]	-	189	Sep. 7	659 (58)	3 (0)
				Sep. 14	590 (77)	59 (0)
				Sep. 27	160 (37)	239 (17)
				Sep. 30	111 (27)	349 (20)
				Oct. 5	49 (16)	173 (21)
	Naha[d]	-	377	Aug. 31	1,584 (18)[b]	64 (0)
				Sep. 16	1,343 (28)[b]	219 (4)[b]
				Oct. 5	1,245 ([c])	67 ([c])
M	Warm Chuck	Aug. 7-8, 14	475	Sep. 1	132 (5)	2 (0)
				Sep. 5	233 (31)	1 (0)
				Sep. 18	417 (31)	137 (9)
				Sep. 26	1,502 (105)	108 (6)
				Oct. 11	311 (11)	108 (21)

[a] Number with tags is in parentheses.
[b] Primary-colored tags from weir tagging are excluded.
[c] Number was not recorded.
[d] Tagging was conducted at the weir.

Table 6.--Counts of three types of tags--bright-red primary, tricolor seconddry, and yellow secondary--during surveys at the Klakas and Naha systems in southern Southeast Alaska, 1983; Chi-square statistics with associated significance levels for tests of equal visibility.

System	Survey	Type of tag: Ocean primary	Tricolor secondary	Yellow secondary	X^2	Significance level
Klakas	1	20	19	19	.03	>.975
	2	25	24	28	.34	>.50
	3	21	15	18	1.00	>.50
	4	18	16	13	.81	>.50
	5	14	11	12	.38	>.50
Naha	1	19*	10	8	.22	>.50
	2	16*	14	18	.50	>.25

*Numbers are not used in test for equal visibility because fish tagged in ocean fisheries were mixed with those tagged at Naha weir.

survey proportions of total tagged fish seen (the weighting reflected our view that estimates from surveys in which few tagged fish were seen were of dubious value for assessing population size).

Information obtained during the tagging studies was used for computing alternative population estimates to those from tagging. Survey counts (alive and dead combined) of both years were corrected to account for unseen fish. Proportions unobserved during surveys were estimated from counts made on systems with weirs during validation and tag visibility studies.

Total escapement to southern Southeast Alaska in either year was the sum of total escapements to the four classes of lake systems. Total escapement to a class was computed as the product of number of lakes and average escapement per lake. Weir counts, tagging estimates, or survey counts were used to estimate average escapements to lakes of each class.

Another estimate of total escapement in 1982 was the product of total escapement in 1983 and the ratio of escapement in 1982 to that in 1983. (This estimate was developed because the first year of the study resulted in less complete data for escapement estimates.) The ratio of escapement in 1982 to that in 1983 was estimated from systems with weirs in both years.

Computation of total escapement estimates for southern Southeast Alaska and evaluation of precision of such estimates were accomplished by the bootstrap method (Efron 1982). Samples of observations, including weir counts, survey counts, and tag and recovery data, used in the computation of a total escapement estimate were resampled (simple random samples were drawn with replacement from original samples with their size equal to that of the originals) to create additional data sets. An estimate of total escapement was computed from each data set. (Details of the computations are provided in later sections of this report.) When total escapement estimates were recomputed hundreds of times in this fashion, the empirical probability distribution of such estimates induced by sampling errors wasapproximated. The mean of the empirical distribution was the point estimate of total escapement, and the interval of estimates corresponding to the central 1 -OC proportion of this distribution (equal tails) provided an approximate (1 -OC) 100% confidence interval.

Estimates from alternative methods were combined to provide a point estimate of total escapement for either year. The point estimate was the weighted average of the alternative estimates with weights inversely proportional to variances of the alternative estimates as determined by bootstrapping. A confidence interval of the point estimate was the intersection of the confidence intenrals for the alternative estimates.

RESULTS AND DISCUSSION

This report documents the computation of total sockeye salmon escapement estimates to southern Southeast Alaska for 1982 and 1983. These computations accounted for the following observations:

1) Substantial initial loss of tagged fish before entry into fresh water from taggings in estuaries required adjustment of population estimates.
2) Potential differences in visibility of tag colors were not detected; therefore no adjustment of estimates was required.
3) In three of five systems at which sockeye salmon were both tagged and counted through a weir, fairly

accurate population estimates were obtained by tagging; but in the other two cases, unpredictable circumstances caused gross error. Hence, population estimates from tagging alone were not trustworthy, and alternative estimates were required.

Many sockeye salmon tagged in the estuaries of weired systems apparently died before arriving at the weir. In 1982, the weir at Warm Chuck was installed after the run had begun, but before tagging; the count was 138 of the 250 (55%) tagged fish. Similar counts from three systems were available from 1983: At Kegan, only 199 of 494 (40%) tagged sockeye salmon went through the weir: at Salmon Bay, 335 of 506 (66%): and at Warm Chuck, 274 of 475 (58%). Information from the weirs and surveys, which covered a substantial part of the escapement of both years, as well as reports from the commercial and subsistence fisheries of Southeast Alaska, did not account for the losses; only 39 (5%) of the 779 missing tagged fish were located. Commercial catches were examined for tags by ADF&G, but no provision was made for monitoring of the subsistence catch: it is assumed that not all tagged fish caught in the subsistence fishery were reported.

Differences in visibility between the two colors of secondary tags and that of primary tags were not detectable during the 1983 special studies (chi-square tests: Table 6). Comparison of the counts at Klakas suggested that possible differences in visibility among tag types were not substantial (Table 6). The Naha visibility experiment was ruined in part when unknown numbers of fish with primary tags from the ocean tagging entered the system, either during a flood while the weir was inoperable, or after the weir was removed. The comparison between the two colors of secondary tags at Naha, however, remained valid. Results (Table 6) also gave no indication of a difference between the two colors of secondary tags,.

The comparison of Petersen estimates with weir counts during the 1983 special validation studies produced mixed results. Estimates for Kegan and Warm Chuck were reasonably accurate, but those for Salmon Bay were not. Our estimate for Kegan was 6,778 fish as compared to the weir count of 8,751 (percent error = -23%). The estimate for Warm Chuck was 3,690 tagged fish as compared to the weir count of 3,395 (percent error = +9%).

The comparison of the estimate obtained by tagging with the weir count for Salmon Bay was of reduced value for two reasons. First, an unknown but large number of small sockeye salmon passed through the weir uncounted, causing errors that could not be eliminated. The escapement observed by our survey teams at Salmon Bay consisted of more than 50% small (size category determined by the subjective judgment of survey crews), presumably early maturing individuals. However, precocious spawners accounted for only 12% of the fish counted at the weir. Second, the escapement count was comparatively large, about 14,000 sockeye salmon. The 335 tagged fish that survived were inadequate to provide an estimate of reasonable precision, with a sampling of 25% or less (Robson and Regier 1964). Using tagged fish, the escapement estimate for Salmon Bay was 56,441 (percent error = 302%).

Tagging estimates were also compared to weir counts at Naha and Klakas, the systems at which tag visibility-was examined in 1983. Two estimates of escapement to either system were made. First, the tagged fish at either weir were assumed unaffected by causes of initial losses of fish tagged in the estuaries. If so, the Petersen estimate for Klakas was 1,655 compared to the weir count of 1,413 (percent error = +17%). The Petersen estimate for Naha was 23,799 compared to the weir count of 4,679 (percent error was +409%). Second, if the fish tagged at the weirs suffered the same losses as our other tag releases in the estuaries in advance of the weirs, an adjustment in the Petersen estimate was needed.

Our adjustment of the Petersen estimates for tagging mortality used the observations on survival from estuary tagging at systems with weirs. Kegan was excluded because survival was lower than at other systems, possibly due to subsistence fishing observed at time of tagging. Thus, three estimates of survival from tagging were used: those from 1982 and 1983 at Warm Chuck, and from Salmon Bay in 1983. Average' survival over the three experiments was 60% (Standard error (SE) = 3.3%). Then the corrected Petersen estimates for Klakas and Naha were 1,025 and 14,635, respectively (corresponding percent errors = -27% and +213%).

The difference between the Petersen estimate and actual count for Naha is not understood. Small sockeye salmon were relatively abundant in Naha when compared to systems other than Salmon Bay: roughly 10% of the individuals seen on one survey were small. Furthermore, some fish had entered the Naha system without being counted, either during a 2-day period of flooding when counting was impossible, or after the weir was removed when the return was assumed complete. Thirteen tagged fish from the ocean taggings, which were to be removed at the weir, were found later during surveys in Naha; these fish represented an additional 1,170 sockeye salmon to the escapement if equal proportions of counted and uncounted escapements had been tagged in the ocean fisheries. Both the small fish and uncounted escapement would cause the Petersen estimate to be greater than the escapement counted at the weir, but the difference seems too great if they alone were responsible.

In summary, tagging estimates and weir counts for 1983 could be compared for five systems. Percent error of the estimate was -23% at Kegan, +9% at Warm Chuck, and -27 to +17% at Klakas (depending on survival rates assumed for tagged fish). The numbers of tagged fish that survived at these places were low (attempts to tag greater numbers were not successful), and errors of this size may have been due to sampling variation rather than bias. Escapements at Salmon Bay and Naha were greatly overestimated with errors over 200%.

Escapement estimation is notoriously difficult, fraught with potential bias and error. Whenever possible, estimates from several sources of information should be computed to protect against gross error. We demonstrated that secondary tagging could provide fairly accurate escapement estimates at the level of tagging used, but that caution in use of such estimates was obviously necessary. An alternative approach to estimating total escapement to southern Southeast Alaska based on survey and weir counts was developed to validate secondary tagging. These two approaches were used for the 1983 escapement study discussed next. Tagging information was too incomplete in 1982 for use in total escapement estimation. As a result, we developed a ratio estimate for escapement in 1982, based on the escapement estimate of 1983, as a check on the value obtained from survey and weir counts. Small-sized fish that could pass through the weirs uncounted were excluded from estimates for both years.

Escapement in 1983

The first estimate of total escapement to southern Southeast Alaska in -1983 was computed from weir counts and secondary tagging results. We tagged sockeye salmon in three L systems (Helm, Dolomi, and Shipley) and two S systems (Miller and Karheen); none of the five systems had weirs (Table 4). Escapements to these systems using the Petersen estimator (survival of tagged fish assumed to be 60%), averaged 5,500 (SE = 2,060) for the L systems, and 2,800 (SE = 1,490) for the S systems. No fish were tagged in M systems, but escapement to the weir at Warm Chuck was 3,395 (Table 2). Finally, 9 of the original 12 V systems were weired in 1983 (Table 2) and had an average escapement of 13,000 (SE = 5,800).

The empirical sampling distribution of the estimate of total escapement was obtained from 1,000 sets of resampled samples drawn from the uncorrected Petersen estimates for three L systems and two S systems, weir counts for nine V systems, and three estimates of tagging survival. Each of the 1,000 sets of samples, together with the single M system, provided the observations by which total escapement to southern Southeast Alaska was computed. The mean of the 1,000 resampled estimates of total escapement (327,000) was our point estimate (90% CI, 213,000-458,000). Precision was slightly exaggerated by this confidence interval (interval was too narrow) because the variation of M systems was not taken into account.

Another estimate of escapement in 1983 was computed from survey and weir counts. Errors in estimating escapements to particular systems, whose populations were both tagged and surveyed, were independent between this approach and the earlier one based on tagging. However, errors of total escapement estimates for classes of systems from the two approaches were partially dependent because both survey counts and tagging estimates were used from certain systems (Helm, Dolomi, Shipley, Miller, and Karheen). Nonetheless, survey counts were also available from systems in which no meaningful tagginglwas done (Red Bay, Kushneahin, Hatchery, Johnson, Ratz, Luck, and Thorns; Table 4).

Either peak or average survey counts were used to estimate escapements to particular systems after correction to account for unseen fish. An estimate of the percent of escapement seen during the survey when the peak count was observed, was obtained from surveys on weired systems (Kegan, Klakas, Naha, and Warm Chuck: Table 5). Salmon Bay was excluded because of the problem with uncounted small fish which had passed through the weir. The average maximum percent of the weir count observed on these four systems was 37 (SE = 6.7). This value could have been too high for use in correcting peak counts of systems without weirs because these systems with weirs were surveyed more frequently than some surveyed systems without weirs. Also, the percent observed for Naha was probably high because the weir count was incomplete. If the estimate of average maximum percent observed was too high, the escapement estimates from expansion of peak counts on the systems without weirs were biased too low. The bias was reduced by using average survey counts in place of peak counts. The corresponding average percent of the weir count observed on the four systems was 24 (SE = 5.3).

Peak and average survey counts obtained in 1983 were corrected for unseen fish to provide our second estimate of total escapement. Peak and average survey counts were obtained from basic observations (Table 4). Average peak count in two of the V systems without weirs was 4,200 (SE = 1,190); the corresponding value for average survey counts in these systems was identical to the average peak count because only single surveys were conducted. Average peak count in six L systems was 1,000 (SE = 420); the corresponding value for average survey counts was 800 (SE = 430). Average peak count in two M systems was 700 (SE = 620); the corresponding value for average survey counts was identical to the average peak count. Finally, the average peak count observed in S systems was 1,400 (SE = 760); the corresponding value for average survey counts was 600 (SE = 210).

The empirical distribution of estimates of total escapement from average or peak survey counts was obtained by resampling each of the four systems (Kegan, Klakas, Naha, and Warm Chuck) and their surveys 1,000 times for estimates of maximum and average percent seen. Next, systems and surveys were resampled for class average (per system) of peak or average (per survey) survey counts. Corrected counts were added to weir counts to estimate total escapement to southern Southeast Alaska. Average survey counts provided an estimate of 318,000 (90% CI, 216,000-466,000). Peak counts provided an estimate of 324,000 (90% CI, 209,000-486,000). The two estimates were highly dependent and of nearly equal precision. Their average provided an estimate of 321,000 from survey counts (90% CI, 216,000-466,000).

Escapement in 1982

Two approaches were also used in estimation of the 1982 escapement. The first approach was based on a comparison of escapements of 1982 and 1983 to seven V systems weired in both years (Table 2, last column). In six of seven cases, the escapements declined from 1982 to 1983. However, escapement at McDonald increased to over threefold that of 1982, and with the increase, its escapement became the largest in southern Southeast Alaska. Overall total escapement to these systems in 1983 was approximately 90% of the corresponding escapement in 1982. Because we had an estimate of the escapement in 1983, we could compute an estimate for 1982 based on the assumption that similar changes occurred in the escapements to the remaining systems. One thousand simple random samples of seven pairs of annual weir counts were drawn with replacement from those of 1982 and 1983 at these seven weirs. The ratio of the 1982 total count to the 1983 total count was computed from each of these samples. Each resampled ratio was multiplied by one of the 1,000 previously computed estimates of total escapement in 1983 based on weir counts plus corrected average survey counts. The average of the 1,000 products, our estimate for 1982 total escapement equaled 482,000 (90% CI, 254,000-913,000).

The second approach to estimating 1982 escapement used survey counts (Table 3) corrected for unseen fish as in 1983. The weir and survey counts of 1983 at Kegan, Klakas, Naha, and Warm Chuck were used to estimate the observed proportion of the escapement seen. This approach required that the proportion seen did not change between years. Evidence for change is not available, although some knowledge on timing of spawning was gained in 1982. If experience increased the proportion of fish seen, corrected survey counts would be low estimates of population size. In 1982, we surveyed 11 systems in addition to the 4 V systems not weired. Average peak count in the V systems was 3,900 (SE = 1,220); the corresponding value for average survey counts was 3,600 (SE = 1,220). We surveyed five L systems (Table 3) and saw an average peak count of 1,100 sockeye salmon (SE = 470); the corresponding value for average survey counts was 1,000 (SE = 490). We surveyed three M systems (Table 3) and saw an even greater average peak count of 1,600 sockeye salmon (SE = 1,010); the corresponding value for average survey counts was 700 (SE = 620). Finally, we surveyed three S systems (Table 3) and saw an average peak count of 746 sockeye salmon (SE = 60); corresponding value for average survey counts was 600 (SE = 260). Estimates of total escapement to southern Southeast Alaska was the sum of weir counts and survey counts, either average or peak, corrected for unseen fish and the number of systems per class. The empirical distribution of these estimates for peak counts provided an estimate of total escapement of 337,000 (90% CI, 254,000-499,000); average survey counts resulted in an estimate of 357,000 (90% CI, 216,000-466,000). The two estimates were of nearly equal precision. Their average provided an estimate of 347,000 from survey counts (90% CI, 254,000-477,000).

Total escapement estimates of sockeye salmon to southern Southeast Alaska by the several approaches were consistent within and between years (Table 7). For 1983, point estimates from survey counts and tagging ranged from 321,000 to 327,000. Both methods provided estimates of nearly the same precision;

confidence intervals were almost completely overlapping. The combined point estimate was 324,000 (90% CI, 216,000-458,000).

For 1982, the estimate from survey counts was 347,000. The partially dependent ratio estimate for 1982 based on multiplying 1983 escapement by relative numbers counted through weirs in both years was considerably greater at 482,000 sockeye salmon. However, the ratio estimate was much less precise than the estimate from survey counts as indicated by widths of confidence intenrals (Table 7): surveys, 223,000; ratio, 659,000. Nonetheless, the lower bound for the ratio estimate, 254,000, was equal to the lower bound of the 1982 survey estimate. The combined point estimate for 1982 escapement was 354,000 (90% CI, 254,000-477,000).

Table 7. --Summary of total escapement estimates to southern Southeast Alaska, 1982 and 1983. Numbers in parentheses are 90% confidence limits.

Method of estimation	Total escapement 1982	Total escapement 1983
Survey counts	347,000 (254,000-499,000)	321,000 (216,000-466,000)
Tagging	- -	327,000 (213,000-458,000)
Weir count ratio	482,000 (254,000-913,000)	- -
Combined	354,000 (254,000-477,000)	324,000 (216,000-458,000)

CONCLUSION

Estimates of total escapement in 1983 from Petersen experiments or survey counts were in agreement, and a combined estimate from both methods was computed as 324,000 fish (90% CI, 216,000-458,000). An estimate of total escapement in 1982 was available from survey counts, and a second estimate was computed from the escapement in 1983 and relative escapements counted during the 2 years the lake systems had weirs. The combined estimate from the two approaches for 1982 was 354,000 (90% CI, 254,000-477,000). These were the first estimates of total sockeye salmon escapement for this region. Fishery managers can now judge future conditions of Southeast Alaskan sockeye populations by comparing population sizes with that documented by this study.

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